

Claims

1. A monitoring system for a fleet of vehicles, comprising:

at least one data acquisition and analysis module (DAAM) mounted on a vehicle in the fleet,

each said DAAM

i) collecting data indicative of measurable attributes of the vehicle,

ii) analyzing said data to generate analysis results that identifies the state of one or more sub-systems of the vehicle based on said measurable attributes, and

iii) transmitting at least a portion of said analysis results;

a control module mounted on the vehicle and in communication with each said DAAM

mounted on the vehicle, said control module

i) collecting said analysis results transmitted from each said DAAM,

ii) analyzing said analysis results so-collected to generate vehicle status results that identify potential sources of vehicle anomalies based on the state of said one or more sub-systems, and

iii) transmitting said analysis results so-collected and at least a portion of said vehicle status

results; and

a terminal module located remotely with respect to the vehicle and in communication with the vehicle as well as other vehicles in the fleet wherein each of the other vehicles in the fleet is equipped with their own said at least one DAAM and said control module, said terminal module

i) collecting, from the fleet of vehicles, said analysis results and said vehicle status results

transmitted from each said control module,

ii) analyzing, for the fleet of vehicles, said analysis results and said vehicle status results transmitted from each said control module to generate fleet results that identify multiple occurrences of said vehicle anomalies and multiple occurrences of ones of said one or more sub-systems operating at a performance level that is unacceptable, and

iii) transmitting said fleet results for use by one or more interested organizations.

2. A monitoring system as in claim 1 wherein said one or more interested organizations comprises one or more organizations responsible for the one or more of operation, maintenance,

monitoring, and manufacturing of the vehicles in the fleet and said one or more sub-systems used in the fleet.

3. A monitoring system as in claim 1 wherein each said DAAM, each said control module and
5 said terminal module includes an expert system for performing said analyzing function associated therewith.

4. A monitoring system as in claim 3 wherein each said expert system is a fuzzy expert system.

10 5. A monitoring system as in claim 1 wherein each said DAAM includes means for providing baseline data for each of said measurable attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes.

6. A monitoring system as in claim 5 wherein said means for providing said baseline data is a
15 memory device.

7. A monitoring system as in claim 5 wherein said means for providing said baseline data is a neural network trained when the vehicle is known to be operating correctly.

20 8. A monitoring system as in claim 1 wherein said terminal module transmits autonomously.

9. A monitoring system as in claim 1 wherein each said DAAM comprises:
programmable means for sampling said data in accordance with user-supplied criteria;
means for providing baseline data for each of said measurable attributes, said baseline data
25 defining an acceptable level of performance for each of said measurable attributes;
a processor coupled to said programmable means and said means for providing said baseline data, said processor analyzing said data so-sampled in relation to said baseline data to generate said analysis results; and

communication means coupled to said processor for broadcasting said analysis results.

10. A monitoring system as in claim 9 wherein said processor incorporates an expert system.

5 11. A monitoring system as in claim 10 wherein said expert system is a fuzzy expert system.

12. A monitoring system for a fleet of vehicles, comprising:
at least one data acquisition and analysis module (DAAM) mounted on a vehicle in the fleet,
each said DAAM having

10 i) a programmable digital interface for collecting data indicative of measurable attributes of
the vehicle,

ii) an expert system coupled to said programmable digital interface for analyzing said data to
generate analysis results that identifies the state of one or more sub-systems of the vehicle based on
said measurable attributes, and

15 iii) communication means coupled to said DAAM's expert system for transmitting at least a
portion of said analysis results;

a control module mounted on the vehicle and in communication with each said DAAM
mounted on the vehicle, said control module having

20 i) communication means for the transmission and reception of signals, said control module's
communication means receiving said analysis results transmitted from each said DAAM, and

ii) an expert system coupled to said control module's communication means for analyzing
said analysis results so-received to generate vehicle status results that summarize the state of
relationships between said one or more sub-systems, wherein said control module's communication
means transmits at least a portion of said vehicle status results; and

25 a terminal module located remotely with respect to the vehicle and in communication with
the vehicle as well as other vehicles in the fleet wherein each of the other vehicles in the fleet is
equipped with their own said at least one DAAM and said control module, said terminal module
having

i) communication means for the transmission and reception of signals, said terminal module's communication means receiving said vehicle status results transmitted from the vehicle and each of the other vehicles in the fleet, and

5 ii) an expert system coupled to said terminal module's communication means for analyzing said vehicle status results so-received to generate fleet results that summarize the state of said one or more sub-systems and said relationships between said one or more sub-systems for the fleet, wherein said terminal module's communication means transmits said fleet results for use by one or more interested organizations.

10 13. A monitoring system as in claim 12 wherein said one or more interested organizations comprises one or more organizations responsible for the one or more of operation, maintenance, monitoring, and manufacturing of the vehicles in the fleet and said one or more sub-systems used in the fleet.

15 14. A monitoring system as in claim 12 wherein each said expert system is a fuzzy expert system.

15. A monitoring system as in claim 12 wherein each said DAAM includes means coupled to said DAAM's expert system for providing baseline data thereto for each of said measurable
20 attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes.

16. A monitoring system as in claim 15 wherein said means for providing said baseline data is a memory device.

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17. A monitoring system as in claim 15 wherein said means for providing said baseline data is a neural network trained when the vehicle is known to be operating correctly.

18. A monitoring system as in claim 12 wherein said terminal module's communication means transmits said fleet results autonomously.

19. A monitoring system for a fleet of vehicles, comprising:

5 at least one data acquisition and analysis module (DAAM) mounted on a vehicle in the fleet, each said DAAM having

i) a programmable digital interface for collecting data indicative of measurable attributes of the vehicle,

10 ii) a fuzzy logic expert system coupled to said programmable digital interface for analyzing said data to generate analysis results that identifies the state of one or more sub-systems of the vehicle based on said measurable attributes, and

iii) communication means coupled to said DAAM's expert system for transmitting at least a portion of said analysis results;

15 a control module mounted on the vehicle and in communication with each said DAAM mounted on the vehicle, said control module having

i) communication means for the transmission and reception of signals, said control module's communication means receiving said analysis results transmitted from each said DAAM, and

20 ii) a fuzzy logic expert system coupled to said control module's communication means for analyzing said analysis results so-received to generate vehicle status results that summarize the state of relationships between said one or more sub-systems, wherein said control module's communication means transmits at least a portion of said vehicle status results;

25 a terminal module located remotely with respect to the vehicle and in communication with the vehicle as well as other vehicles in the fleet wherein each of the other vehicles in the fleet is equipped with their own said at least one DAAM and said control module, said terminal module having

i) communication means for the transmission and reception of signals, said terminal module's communication means receiving said vehicle status results transmitted from the vehicle and each of the other vehicles in the fleet, and

ii) a fuzzy logic expert system coupled to said terminal module's communication means for analyzing said vehicle status results so-received to generate fleet results that summarize the state of said one or more sub-systems and said relationships between said one or more sub-systems for the fleet, wherein said terminal module's communication means transmits said fleet results for use by one or more interested organizations; and

each said fuzzy logic expert system incorporating a tool for development thereof, said tool being supplied with a plurality of decision rules indicative of user-supplied consequences based on user-supplied antecedents indicative of said measurable attributes, said tool

i) generating a design vector of parameters that defines all antecedent and consequence membership function distributions associated with said plurality of decision rules,

ii) configuring a fuzzy inference algorithm with said user-supplied antecedents and said design vector, wherein test consequences are generated thereby,

iii) comparing said test consequences with said user-supplied consequences wherein differences therebetween are generated, and

iv) minimizing said differences by optimizing said design vector wherein said fuzzy inference algorithm so-configured with said user-supplied antecedents and said design vector so-optimized defines said fuzzy logic expert system.

20. A monitoring system as in claim 19 wherein each said DAAM includes means coupled to said DAAM's expert system for providing baseline data thereto for each of said measurable attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes.

21. A monitoring system as in claim 20 wherein said means for providing said baseline data is a memory device.

22. A monitoring system as in claim 20 wherein said means for providing said baseline data is a neural network trained when the vehicle is known to be operating correctly.

23. A monitoring system as in claim 19 wherein said terminal module's communication means transmits said fleet results autonomously.

5 24. A monitoring system as in claim 19 wherein said one or more interested organizations comprises one or more organizations responsible for the one or more of operation, maintenance, monitoring, and manufacturing of the vehicles in the fleet and said one or more sub-systems used in the fleet.

10 25. A monitoring system for a group of systems, comprising:
at least one data acquisition and analysis module (DAAM) mounted on a system in the group, each said DAAM
i) collecting data indicative of measurable attributes of the system,
ii) analyzing said data to generate analysis results that identifies the state of one or more sub-
15 systems of the system based on said measurable attributes, and
iii) transmitting at least a portion of said analysis results;
a control module mounted on the system and in communication with each said DAAM
mounted on the system, said control module
i) collecting said analysis results transmitted from each said DAAM,
20 ii) analyzing said analysis results so-collected to generate system status results that identify potential sources of system anomalies based on the state of said one or more sub-systems, and
iii) transmitting said analysis results so-collected and at least a portion of said system status results; and
a terminal module located remotely with respect to the system and in communication with
25 the system as well as other systems in the group wherein each of the other systems in the group is equipped with their own said at least one DAAM and said control module, said terminal module
i) collecting, from the group of systems, said analysis results and said system status results transmitted from each said control module,

ii) analyzing, for the group of systems, said analysis results and said system status results transmitted from each said control module to generate group results that identify multiple occurrences of said system anomalies and multiple occurrences of ones of said one or more sub-systems operating at a performance level that is unacceptable, and

5 iii) transmitting said group results for use by one or more interested organizations.

26. A monitoring system as in claim 25 wherein said one or more interested organizations comprises one or more organizations responsible for the one or more of operation, maintenance, monitoring, and manufacturing of the structures in the group and said one or more sub-systems used
10 in the group.

27. A monitoring system as in claim 25 wherein each said DAAM, each said control module and said terminal module includes an expert system for performing said analyzing function associated therewith.

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28. A monitoring system as in claim 27 wherein each said expert system is a fuzzy expert system.

29. A monitoring system as in claim 25 wherein each said DAAM includes means for providing
20 baseline data for each of said measurable attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes.

30. A monitoring system as in claim 29 wherein said means for providing said baseline data is a memory device.

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31. A monitoring system as in claim 29 wherein said means for providing said baseline data is a neural network trained when the structure is known to be operating correctly.

32. A monitoring system as in claim 25 wherein said terminal module transmits autonomously.

33. A monitoring system as in claim 25 wherein each said DAAM comprises:

programmable means for sampling said data in accordance with user-supplied criteria;

means for providing baseline data for each of said measurable attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes;

a processor coupled to said programmable means and said means for providing said baseline data, said processor analyzing said data so-sampled in relation to said baseline data to generate said analysis results; and

communication means coupled to said processor for broadcasting said analysis results.

34. A monitoring system as in claim 33 wherein said processor incorporates an expert system.

35. A monitoring system as in claim 34 wherein said expert system is a fuzzy expert system.

36. A monitoring system as in claim 25 wherein the group of systems is selected from the group consisting of manufacturing plants, structures including buildings and bridges, vehicles, and patients under medical care.

37. A monitoring system for a group of systems, comprising:

at least one data acquisition and analysis module (DAAM) mounted on a system in the group, each said DAAM having

i) a programmable digital interface for collecting data indicative of measurable attributes of the system,

ii) an expert system coupled to said programmable digital interface for analyzing said data to generate analysis results that identifies the state of one or more sub-systems of the system based on said measurable attributes, and

iii) communication means coupled to said DAAM's expert system for transmitting at least a

portion of said analysis results;

a control module mounted on the structure and in communication with each said DAAM mounted on the system, said control module having

i) communication means for the transmission and reception of signals, said control module's communication means receiving said analysis results transmitted from each said DAAM, and

ii) an expert system coupled to said control module's communication means for analyzing said analysis results so-received to generate system status results that summarize the state of relationships between said one or more sub-systems, wherein said control module's communication means transmits at least a portion of said system status results; and

a terminal module located remotely with respect to the system and in communication with the system as well as other systems in the group wherein each of the other systems in the group is equipped with their own said at least one DAAM and said control module, said terminal module having

i) communication means for the transmission and reception of signals, said terminal module's communication means receiving said system status results transmitted from the system and each of the other systems in the group, and

ii) an expert system coupled to said terminal module's communication means for analyzing said system status results so-received to generate group results that summarize the state of said one or more sub-systems and said relationships between said one or more sub-systems for the group, wherein said terminal module's communication means transmits said group results for use by one or more interested organizations.

38. A monitoring system as in claim 37 wherein said one or more interested organizations comprises one or more organizations responsible for the one or more of operation, maintenance, monitoring, and manufacturing of the systems in the group and said one or more sub-systems used in the group.

39. A monitoring system as in claim 37 wherein each said expert system is a fuzzy expert

system.

40. A monitoring system as in claim 37 wherein each said DAAM includes means coupled to said DAAM's expert system for providing baseline data thereto for each of said measurable
5 attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes.

41. A monitoring system as in claim 40 wherein said means for providing said baseline data is a memory device.

10 42. A monitoring system as in claim 40 wherein said means for providing said baseline data is a neural network trained when the system is known to be operating correctly.

43. A monitoring system as in claim 37 wherein said terminal module's communication means
15 transmits said group results autonomously.

44. A monitoring system as in claim 37 wherein the group of systems is selected from the group consisting of manufacturing plants, structures including buildings and bridges, vehicles, and patients under medical care.

20 45. A monitoring system for a group of systems, comprising:
at least one data acquisition and analysis module (DAAM) mounted on a system in the group, each said DAAM having
i) a programmable digital interface for collecting data indicative of measurable attributes of
25 the system,
ii) a fuzzy logic expert system coupled to said programmable digital interface for analyzing said data to generate analysis results that identifies the state of one or more sub-systems of the system based on said measurable attributes, and

iii) communication means coupled to said DAAM's expert system for transmitting at least a portion of said analysis results;

a control module mounted on the system and in communication with each said DAAM mounted on the system, said control module having

5 i) communication means for the transmission and reception of signals, said control module's communication means receiving said analysis results transmitted from each said DAAM, and

ii) a fuzzy logic expert system coupled to said control module's communication means for analyzing said analysis results so-received to generate system status results that summarize the state of relationships between said one or more sub-systems, wherein said control module's

10 communication means transmits at least a portion of said system status results;

a terminal module located remotely with respect to the system and in communication with the system as well as other systems in the group wherein each of the other systems in the group is equipped with their own said at least one DAAM and said control module, said terminal module having

15 i) communication means for the transmission and reception of signals, said terminal module's communication means receiving said system status results transmitted from the system and each of the other systems in the group, and

ii) a fuzzy logic expert system coupled to said terminal module's communication means for analyzing said system status results so-received to generate group results that summarize the state of
20 said one or more sub-systems and said relationships between said one or more sub-systems for the group, wherein said terminal module's communication means transmits said group results for use by one or more interested organizations; and

each said fuzzy logic expert system incorporating a tool for development thereof, said tool being supplied with a plurality of decision rules indicative of user-supplied consequences based on
25 user-supplied antecedents indicative of said measurable attributes, said tool

i) generating a design vector of parameters that defines all antecedent and consequence membership function distributions associated with said plurality of decision rules,

ii) configuring a fuzzy inference algorithm with said user-supplied antecedents and said

design vector, wherein test consequences are generated thereby,

iii) comparing said test consequences with said user-supplied consequences wherein differences therebetween are generated, and

iv) minimizing said differences by optimizing said design vector wherein said fuzzy inference algorithm so-configured with said user-supplied antecedents and said design vector so-optimized defines said fuzzy logic expert system.

46. A monitoring system as in claim 45 wherein each said DAAM includes means coupled to said DAAM's expert system for providing baseline data thereto for each of said measurable attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes.

47. A monitoring system as in claim 46 wherein said means for providing said baseline data is a memory device.

48. A monitoring system as in claim 47 wherein said means for providing said baseline data is a neural network trained when the system is known to be operating correctly.

49. A monitoring system as in claim 45 wherein said terminal module's communication means transmits said group results autonomously.

50. A monitoring system as in claim 45 wherein said one or more interested organizations comprises one or more organizations responsible for the one or more of operation, maintenance, monitoring, and manufacturing of the systems in the group and said one or more sub-systems used in the group.

51. A monitoring system for a system, comprising:
at least one data acquisition and analysis module (DAAM) mounted on the system, each

said DAAM

i) collecting data indicative of measurable attributes of the system,

ii) analyzing said data to generate analysis results that identifies the state of one or more sub-systems of the system based on said measurable attributes, and

5 iii) transmitting at least a portion of said analysis results;

a control module mounted on the system and in communication with each said DAAM mounted on the system, said control module

i) collecting said analysis results transmitted from each said DAAM,

10 ii) analyzing said analysis results so-collected to generate system status results that identify potential sources of system anomalies based on the state of said one or more sub-systems, and

iii) transmitting said analysis results so-collected and at least a portion of said system status results for use by one or more interested organizations.

52. A monitoring system as in claim 51 wherein said one or more interested organizations
15 comprises one or more organizations responsible for the one or more of operation, maintenance, monitoring and manufacturing of the system and said one or more sub-systems used in the system.

53. A monitoring system as in claim 51 wherein each said DAAM, each said control module
20 and said terminal module includes an expert system for performing said analyzing function associated therewith.

54. A monitoring system as in claim 53 wherein each said expert system is a fuzzy expert system.

25 55. A monitoring system as in claim 51 wherein each said DAAM includes means for providing baseline data for each of said measurable attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes.

56. A monitoring system as in claim 55 wherein said means for providing said baseline data is a memory device.

57. A monitoring system as in claim 55 wherein said means for providing said baseline data is a neural network trained when the structure is known to be operating correctly.

58. A monitoring system as in claim 51 wherein said control module transmits autonomously.

59. A monitoring system as in claim 51 wherein each said DAAM comprises:
programmable means for sampling said data in accordance with user-supplied criteria;
means for providing baseline data for each of said measurable attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes;
a processor coupled to said programmable means and said means for providing said baseline data, said processor analyzing said data so-sampled in relation to said baseline data to generate said analysis results; and
communication means coupled to said processor for broadcasting said analysis results.

60. A monitoring system as in claim 59 wherein said processor incorporates an expert system.

61. A monitoring system as in claim 60 wherein said expert system is a fuzzy expert system.

62. A monitoring system as in claim 51 wherein the system is selected from the group consisting of a manufacturing plant, a structure including a building and a bridge, a vehicle, and a patient under medical care.

63. A monitoring system for a system, comprising:
at least one data acquisition and analysis module (DAAM) mounted on a system, each said DAAM having

i) a programmable digital interface for collecting data indicative of measurable attributes of the system,

ii) an expert system coupled to said programmable digital interface for analyzing said data to generate analysis results that identifies the state of one or more sub-systems of the system based on said measurable attributes, and

iii) communication means coupled to said DAAM's expert system for transmitting at least a portion of said analysis results;

a control module mounted on the system and in communication with each said DAAM mounted on the system, said control module having

i) communication means for the transmission and reception of signals, said control module's communication means receiving said analysis results transmitted from each said DAAM, and

ii) an expert system coupled to said control module's communication means for analyzing said analysis results so-received to generate system status results that summarize the state of relationships between said one or more sub-systems, wherein said control module's communication means transmits at least a portion of said system status results for use by one or more interested organizations.

64. A monitoring system as in claim 63 wherein said one or more interested organizations comprises one or more organizations responsible for the one or more of operation, maintenance, monitoring, and manufacturing of the system and said one or more sub-systems used in the system.

65. A monitoring system as in claim 63 wherein each said expert system is a fuzzy expert system.

66. A monitoring system as in claim 63 wherein each said DAAM includes means coupled to said DAAM's expert system for providing baseline data thereto for each of said measurable attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes.

67. A monitoring system as in claim 66 wherein said means for providing said baseline data is a memory device.

5 68. A monitoring system as in claim 66 wherein said means for providing said baseline data is a neural network trained when the system is known to be operating correctly.

69. A monitoring system as in claim 63 wherein said control module's communication means transmits said system results autonomously.

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70. A monitoring system as in claim 63 wherein the system is selected from the group consisting of a manufacturing plant, a structure including a building and a bridge, a vehicle, and a patient under medical care.

15 71. A monitoring system for a system, comprising:
at least one data acquisition and analysis module (DAAM) mounted on the system, each said DAAM having
i) a programmable digital interface for collecting data indicative of measurable attributes of the system,
20 ii) a fuzzy logic expert system coupled to said programmable digital interface for analyzing said data to generate analysis results that identifies the state of one or more sub-systems of the system based on said measurable attributes, and
iii) communication means coupled to said DAAM's expert system for transmitting at least a portion of said analysis results;
25 a control module mounted on the system and in communication with each said DAAM mounted on the system, said control module having
i) communication means for the transmission and reception of signals, said control module's communication means receiving said analysis results transmitted from each said DAAM, and

ii) a fuzzy logic expert system coupled to said control module's communication means for analyzing said analysis results so-received to generate system status results that summarize the state of relationships between said one or more sub-systems, wherein said control module's communication means transmits at least a portion of said system status results for use by one or more interested organizations.

72. A monitoring system as in claim 71 wherein each said DAAM includes means coupled to said DAAM's expert system for providing baseline data thereto for each of said measurable attributes, said baseline data defining an acceptable level of performance for each of said measurable attributes.

73. A monitoring system as in claim 72 wherein said means for providing said baseline data is a memory device.

74. A monitoring system as in claim 73 wherein said means for providing said baseline data is a neural network trained when the structure is known to be operating correctly.

75. A monitoring system as in claim 71 wherein said control module's communication means transmits said system results autonomously.

76. A monitoring system as in claim 71 wherein said one or more interested organizations comprises one or more organizations responsible for the one or more of operation, maintenance, monitoring, and manufacturing of the system and said plurality of sub-systems used in the system.

77. A monitoring system as in claim 71 wherein the system is selected from the group consisting of a manufacturing plant, a structure including a building and a bridge, a vehicle, and a patient under medical care.